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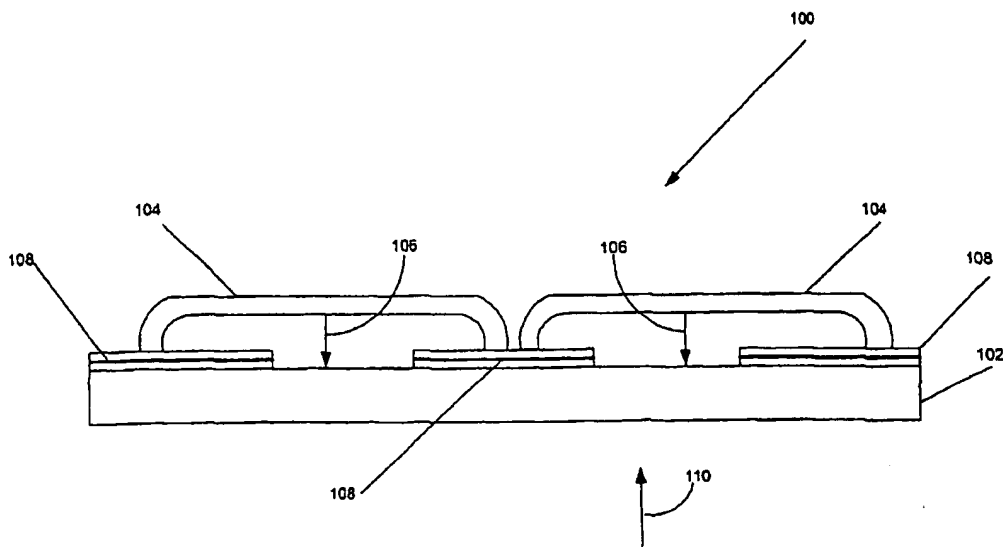
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(54) Title: A DEVICE HAVING A LIGHT-ABSORBING MASK A METHOD FOR FABRICATING SAME



(57) Abstract: The invention provides a method for fabricating an optical device comprising at least one optical component formed on a transparent substrate. The method comprises determining an area of the substrate that is to be lightabsorbing; and fabricating a light-absorbing mask on the determined area prior to fabricating the at least one optical component. The invention also provides an optical device comprising a substrate (102); and first and second optical components formed on the substrate, wherein the first optical component (104) has two modes, each mode producing a different optical response to light incident thereupon, and wherein the second optical component (108) absorbs light and is formed on the substrate before the first optical component is formed.

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## **A DEVICE HAVING A LIGHT-ABSORBING MASK AND A METHOD FOR FABRICATING SAME**

### **FIELD OF THE INVENTION**

**[0001]** This invention relates to optical devices. In particular it relates to micro-optical electromechanical devices and to a method for fabricating same.

### **BACKGROUND**

**[0002]** Today, a wide variety of optical devices such as Microelectromechanical Systems (MEMS) devices may be fabricated using micromachining and microelectronic fabrication techniques.

**[0003]** For example in some cases, MEMS devices may include optical components and are more specifically referred to as micro-opto-electro-mechanical systems or "MOEMS" devices. One example of such a MOEMS device is the Interferometric Modulator (IMOD) device described in U.S. Patent 5,835,255. The IMOD devices of U.S. Patent 5,835,255 may be fabricated in an array and used in a reflective display wherein each IMOD functions as a pixel to provide a desired optical response.

**[0004]** In order to improve the desired optical response, the contribution of reflected ambient light from certain inactive areas of the IMODS should be reduced. Thus, these inactive areas of the IMODS should be made to be light-absorbing, typifying a need to mask-off or make light-absorbing inactive areas in optical devices in general.

### **SUMMARY OF THE INVENTION**

**[0005]** According to one aspect of the invention there is provided a method for fabricating a device comprising at least one optical component formed on a transparent substrate, the method comprising determining an area of the substrate that is to be light absorbing; and fabricating a light-absorbing mask on the determined area prior to fabricating at least one optical component.

**[0006]** According to a second aspect of the invention, there is provided a device comprising a substrate; and first and second optical components formed on the substrate, wherein the first optical component has two modes, each producing a different optical response to light incident thereupon, and wherein

the second optical component absorbs the light and is formed on the substrate before the first optical component is formed.

**[0007]** According to a third aspect of the invention there is provided a method for fabricating a device, the method comprising forming a static optical component on a substrate, wherein the static optical component absorbs light; and forming a dynamic optical component adjacent to the static optical component, wherein the dynamic optical component comprises a driven and an undriven state each having a characteristic optical response to incident light.

**[0008]** According to a further aspect of the invention there is provided a device comprising a substrate; a static optical component on the substrate, wherein the static optical component absorbs the light; and a dynamic optical component adjacent to the static optical component, wherein the dynamic optical component comprises a driven and an undriven state each having a characteristic optical response to incident light.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0009]** Figure 1 of the drawings shows an end view of a display having inactive areas which have been masked-off in accordance with the present invention;

**[0010]** Figure 2 of the drawings shows a cross-section through a MEMS device having a black mask or light-absorbing region in accordance with one embodiment of the invention;

**[0011]** Figure 3 shows another embodiment of a MEMS device having a black mask or light-absorbing region in accordance with another embodiment of the invention;

**[0012]** Figure 4 shows the various layers making up the light-absorbing or black mask layers of the MEMS device Figure 2; and

**[0013]** Figures 5A to 5G show various steps in the fabrication of a MEMS device in accordance with the invention.

#### **DETAILED DESCRIPTION**

**[0014]** In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the invention. It will be apparent, however, to one skilled in the art that the invention can be practiced without these specific details.

**[0015]** Reference in this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments. Moreover, various features are described which may be exhibited by some embodiments and not by others. Similarly, various requirements are described which may be requirements for some embodiments but not other embodiments.

**[0016]** The present invention discloses, in one embodiment, a MEMS device in the form of a MOEMS device comprising a static optical component and a dynamic optical component, wherein the static optical component acts as "black mask" to absorb ambient or stray light thereby to improve the optical response of the dynamic optical component.

**[0017]** Although a MEMS device which includes an IMOD will be used to describe the present invention, it is to be understood that the invention covers other optical devices such as various imaging display and optoelectronic devices in general, which have inactive areas which are required to be light-absorbing, but which do not include IMODS.

**[0018]** Referring now to Figure 1 of the drawings, an end view of display device 100 is shown. It is to be understood that many components of the display 100 have been omitted so as not to obscure the present invention. The display device 100 includes two active optical components in the form of IMOD devices 104 which typically comprise an arrangement of reflective films which when driven towards a substrate 102 in a direction indicated by arrows 106 produces a desired optical response. The operation of the IMOD devices 104 has been described in U.S. Patent 5,835,255 which is hereby incorporated by reference. Reference numerals 108 indicate inactive areas of the IMOD devices 104 which are required to be light-absorbing or to function as a "black mask" so that when a viewer looks at the display 100 from a direction indicated by arrow 110, the actual optical response produced by the IMOD devices 104 is not degraded by the reflection of ambient light from the inactive areas 108.

**[0019]** Each inactive area 108 may be fabricated from materials selected to have an optical response which absorbs or attenuates light. According to embodiments of the invention, each inactive area 108 may be fabricated as a stack of thin films. For example, in one embodiment, the stack of thin films may comprise a non-light-absorbing dielectric layer sandwiched between two light reflecting chrome layers, as will be more fully described below. In other embodiments, the inactive areas 108 may comprise a single layer of organic or inorganic materials which attenuates or absorbs light.

**[0020]** Figure 2 of the drawings shows a cross section through an IMOD device 200 in accordance with one embodiment of the invention. The IMOD device 200 includes an active component comprising a chrome reflective layer 204, a silicon oxide layer 206, an air gap 208, and a mechanical membrane 210 fabricated on a substrate 202. The mechanical membrane 210 is supported by polymer posts 212. In use, mechanical membrane 210 is driven to contact silicon oxide layer 206 to produce a desired optical response when viewed from the direction indicated by arrow 214.

**[0021]** Areas of each IMOD 200 on which the polymer posts 212 are formed are not part of the active component of the IMOD and therefore need to be light-absorbing in order to reduce stray or ambient light interfering with the desired optical response of the active IMOD components. These inactive areas define static components which are indicated by encircled areas 216, and are fabricated to form a stack of films selected so that the stack has the optical property that it is light-absorbing. In one embodiment, the invention involves determining which areas of substrate 202 needs to be light-absorbing and fabricating a light-absorbing or black mask on the determined areas prior to forming the active optical components of the IMODS. The black mask may include a stack of thin films which in one embodiment may comprise a chrome base 218, an oxide middle layer 220 and the chrome layers 204.

**[0022]** Referring now to Figure 3 of the drawings, reference numeral 300 generally indicates another embodiment of an IMOD device in accordance with one aspect of the invention. IMOD device 300 is similar to the IMOD device 200 and accordingly like or similar reference numerals have been used to indicate like or similar components. The main difference between the IMOD

300 and the IMOD 200 is that the entire polymer post 212 comprises of an organic material e.g., a photo-definable black resin such as the material known as DARC 100 by Brewer Science Inc., that functions effectively as a light-absorbing or black mask. One advantage of the IMOD 300 is that the posts 212 perform two functions. Firstly, the posts 212 function as a mechanical support for mechanical membrane 210. Secondly the posts 212 function as an optical mask to mask off or make light-absorbing inactive areas of the IMOD.

**[0023]** Figure 4 shows a schematic drawing wherein various layers making up thin film black mask in accordance with one embodiment of the invention is shown.

**[0024]** Referring to Figure 4, a thin film black mask 402 shown fabricated on substrate 400. The black mask 402 comprises three layers of film which includes a chrome layer 404, a silicon oxide layer 406 and an aluminum layer 408. Various materials may be selected to produce the black mask. In one embodiment, the films which make up the black mask are the same films which are used in the fabrication of the active IMOD components, thus making it possible to use the same deposition parameters to fabricate the inactive and the active components.

**[0025]** The various stages in the manufacture of the thin film black mask 402 will now be described with reference to Figures 5A-5G of the drawings.

**[0026]** Referring to Figure 5A, after an initial preparatory step wherein a glass substrate 500 is prepared, e.g. cleaned, a reflective chrome layer 502 is deposited, e.g. by sputter coating it onto substrate 500. In one embodiment, the thickness of chrome layer 502 may be about 60 angstroms.

**[0027]** Thereafter, the chrome layer 502 is patterned and developed using conventional techniques to leave outcrops of chrome which will serve as a base layer for a thin film stack which serves as a black mask (see Fig. 5B).

**[0028]** A black mask oxide layer, e.g.  $\text{SiO}_2$ , typically about 300 to 800 angstroms is then deposited by sputter coating. The thickness of the black mask oxide layer depends on the quality of the black state that is required.

**[0029]** Next, a further reflective chrome layer 506 is sputter coated on the black mask oxide layer 504. The layer 506 is typically about 60 angstroms

thick, its exact thickness being dependent on the required brightness of the ultimate display, a thinner layer yielding a brighter display.

[0030] Thereafter, layers 508 and 510 are respectively sputter coated on layer 506. Layer 508 comprises silicon oxide and is about 300 to 800 angstroms whereas the layer 510 is a sacrificial layer comprising molybdenum and will typically be about 0.2 to 1.2 microns thick. Thus, layers 504 to 510 define a thick film stack on substrate 502 as can be seen in Figure 5C.

[0031] Referring to Figure 5D, a patterning and an etching step is performed to form recesses 512 which extend through the thin film stack to chrome outcrops 502.

[0032] Referring to Figure 5E, polymer posts 514 are formed in recesses 512 by spinning a negative photo-resist material, e.g. the material known as NR7-350P by Futurex Inc., over the thin film stack; exposing it through a suitable mask and developing to form posts 514. These steps are conventional and therefore have not been further described.

[0033] Referring now to Figure 5F, a mechanical membrane 516 comprising an aluminum alloy, in one embodiment, is deposited by sputter coating it onto the molybdenum layer 510.

[0034] Thereafter, the molybdenum layer 510 is etched leaving an air gap 516 as shown in Figure 5G of the drawings.

[0035] Although the present invention has been described with reference to specific exemplary embodiments, it will be evident that the various modification and changes can be made to these embodiments without departing from the broader spirit of the invention as set forth in the claims. Accordingly, the specification and drawings are to be regarded in an illustrative sense rather than in a restrictive sense.



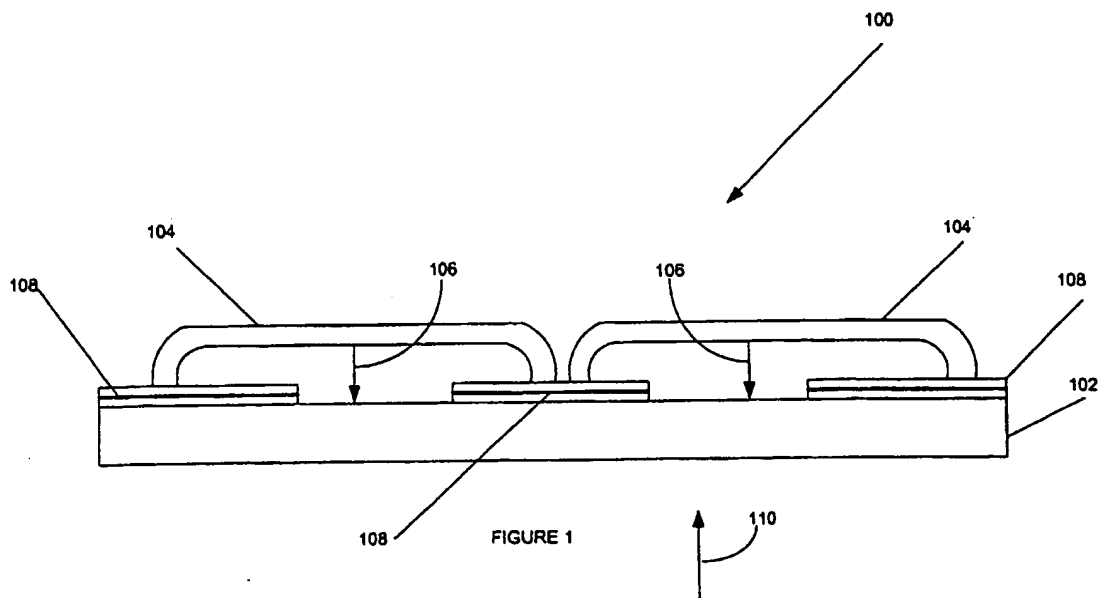
## CLAIMS

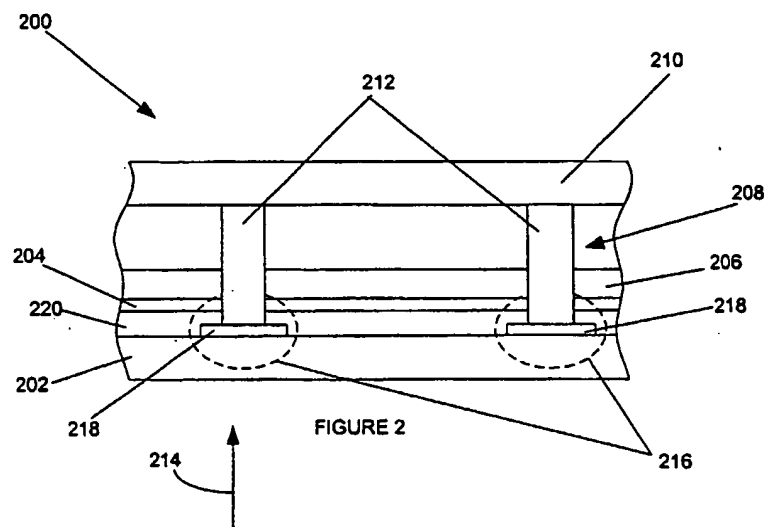
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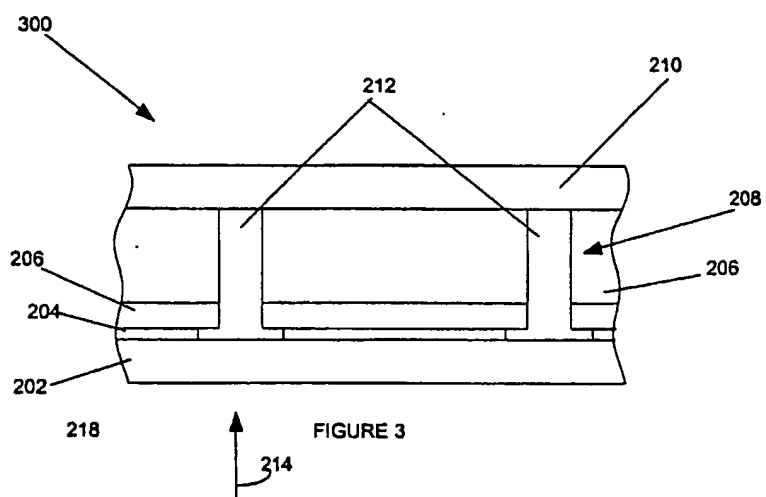
1. A method for fabricating an optical device comprising at least one active optical component formed on a transparent substrate, the method comprising:  
determining an area of the substrate that is to be light-absorbing wherein the determined area is laterally offset from the at least one active optical component; and  
fabricating a light-absorbing mask on the determined area prior to fabricating the at least one active optical component.
2. The method of claim 1, wherein the active optical component comprises a pixel, the light-absorbing area being an area bordering the pixel.
3. The method of claim 2, wherein the fabricating comprises depositing a first light-reflecting layer on the substrate, depositing a non-light-absorbing dielectric layer on the first light-reflecting layer; and depositing a second light-reflecting layer on non-light absorbing dielectric layer.
4. The method of claim 3, wherein the first and second light-reflecting layers comprise materials are metallic.
5. The method of claim 4, wherein the non-light absorbing dielectric layer comprises an oxide layer.
6. The method of claim 2, wherein the pixel is defined by an interferometric modulator.
7. The method of claim 1, wherein the light-absorbing mask comprises an organic material.
8. The method of claim 7, wherein the organic material comprises a photo-definable black resin.

9. An optical device comprising:  
a substrate; and  
first and second optical components formed on the substrate, wherein the first optical component has two modes, each mode producing a different optical response to light incident thereupon, and wherein the second optical component absorbs light and is formed on the substrate before the first optical component is formed.
10. The device of claim 9, wherein the first optical component comprises an interferometric modulator.
11. The device of claim 9, wherein the second optical component is formed around the interferometric modulator.
12. The device of claim 9, wherein the second optical component comprises an organic material.
13. The device of claim 9, wherein a second optical component comprises a film stack.
14. The device of claim 13, wherein the film stack comprises a non-light-absorbing dielectric material sandwiched between two layers of chrome.
15. A method for microfabricating an optical device, the method comprising:  
forming a static optical component on a substrate, wherein the static optical component absorbs light; and  
forming a dynamic optical component adjacent to the static optical component, wherein the dynamic optical component includes a driven and an undriven state each state having a characteristic optical response to incident light.

16. The method of claim 15, wherein the dynamic optical component comprises an interferometric modulator.
17. The method of claim 15, wherein the static optical component comprises a film stack.
18. The method of claim 17, wherein the film stack comprises a non-light-absorbing dielectric material sandwiched between two light-reflecting materials.
19. The method of claim 15, wherein the static optical component forms a mechanical support for portions of the dynamic optical component.
20. An optical device comprising:
  - a substrate;
  - a static optical component on the substrate, wherein the static optical component absorbs light; and
  - a dynamic optical component adjacent to the static optical component, wherein the dynamic optical component includes a driven and an undriven state each state having a characteristic optical response to incident light.
21. The device of claim 20, wherein the dynamic optical component comprises an interferometric modulator.
22. The device of claim 19, wherein the static optical component comprises a film stack.
23. The device of claim 22, wherein the film stack comprises a non-light absorbing dielectric material sandwiched between two light reflecting materials.
24. The device of claim 19, wherein the static optical component forms a mechanical support for portions of the dynamic optical component.







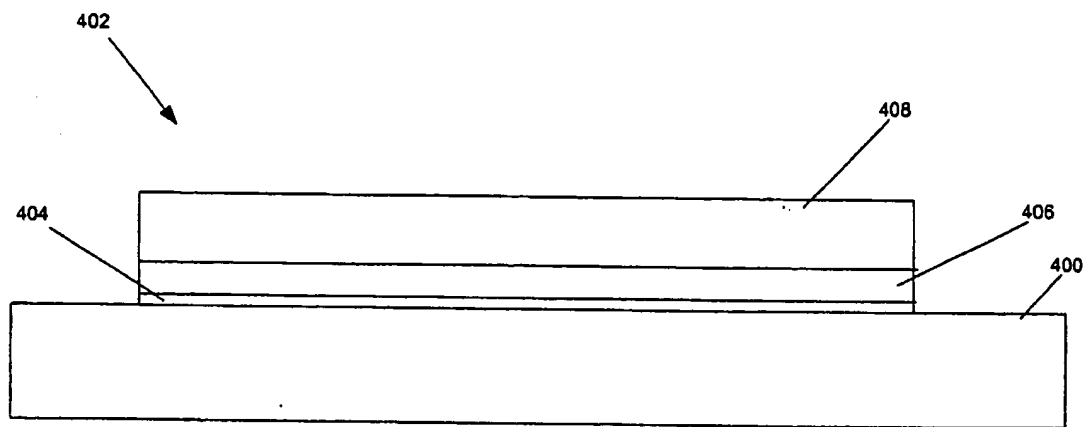


FIGURE 4

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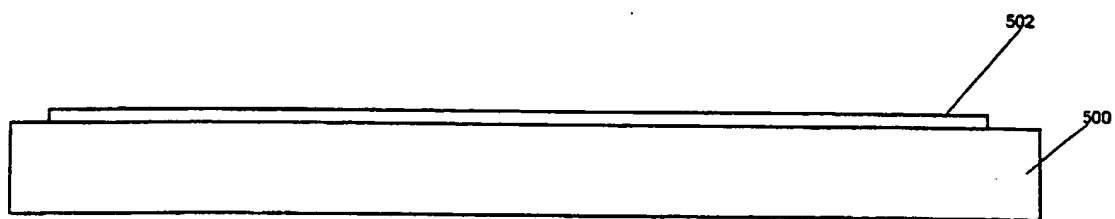


FIGURE 5A



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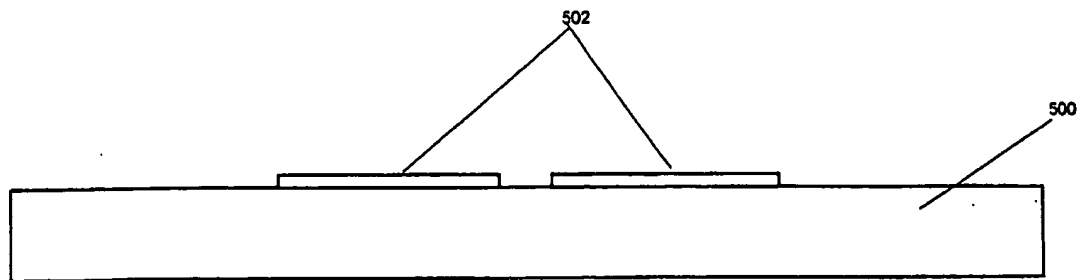
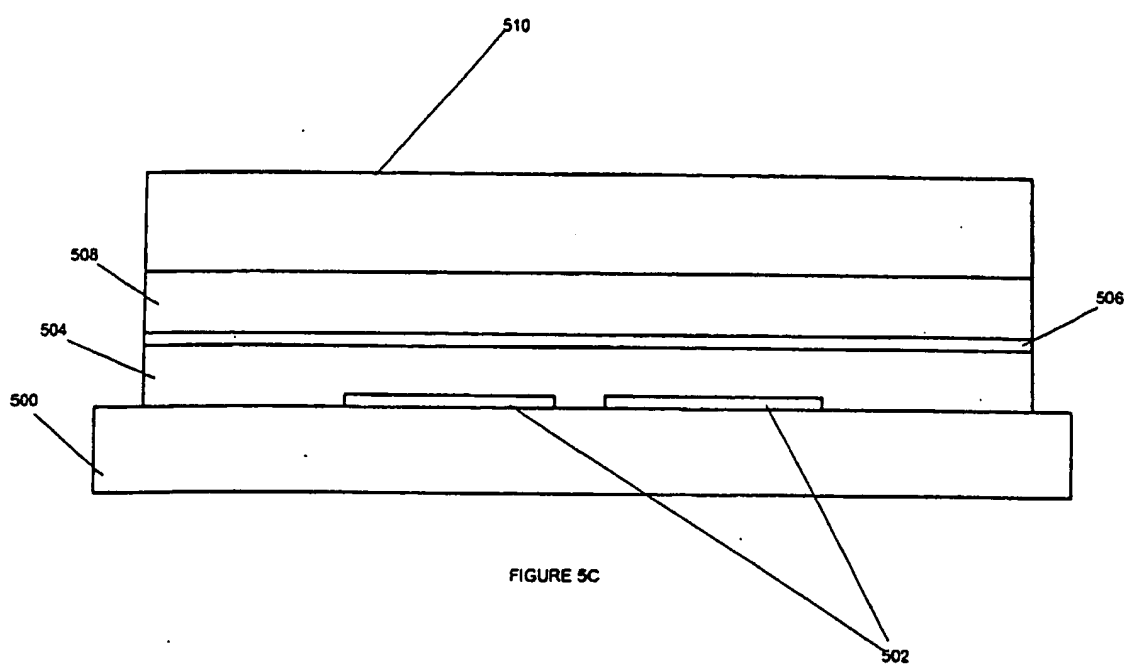
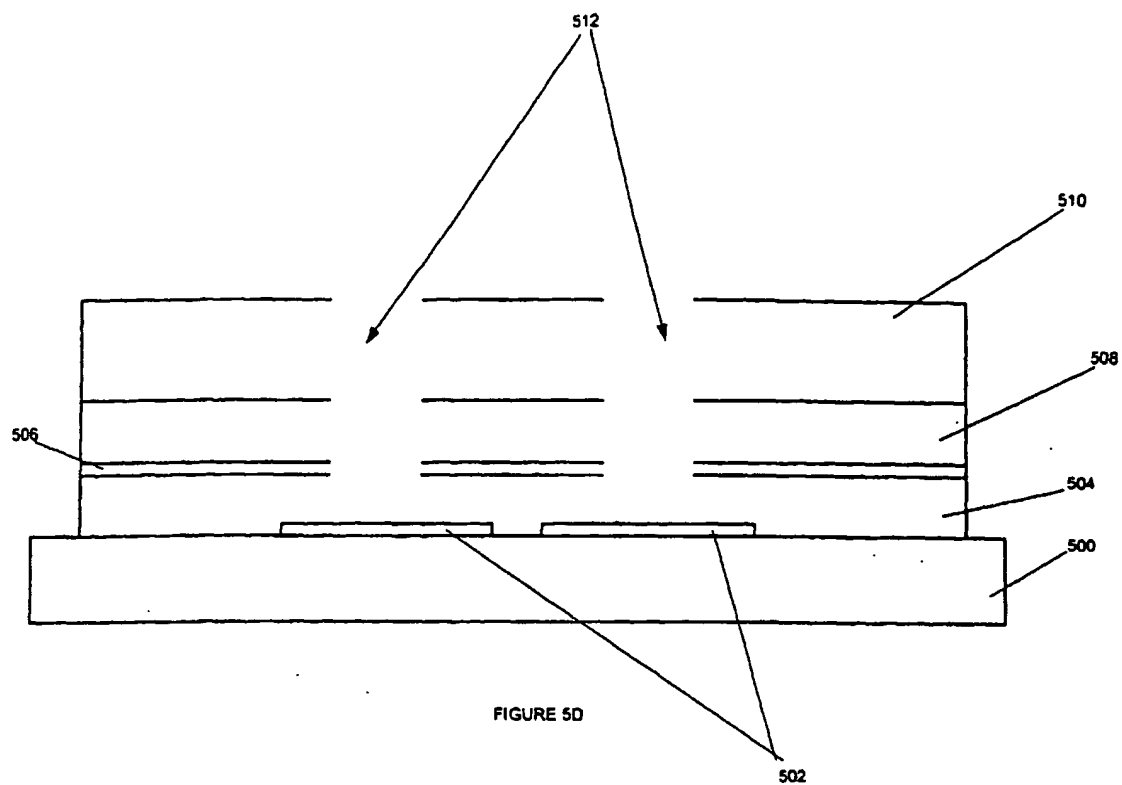


FIGURE 5B

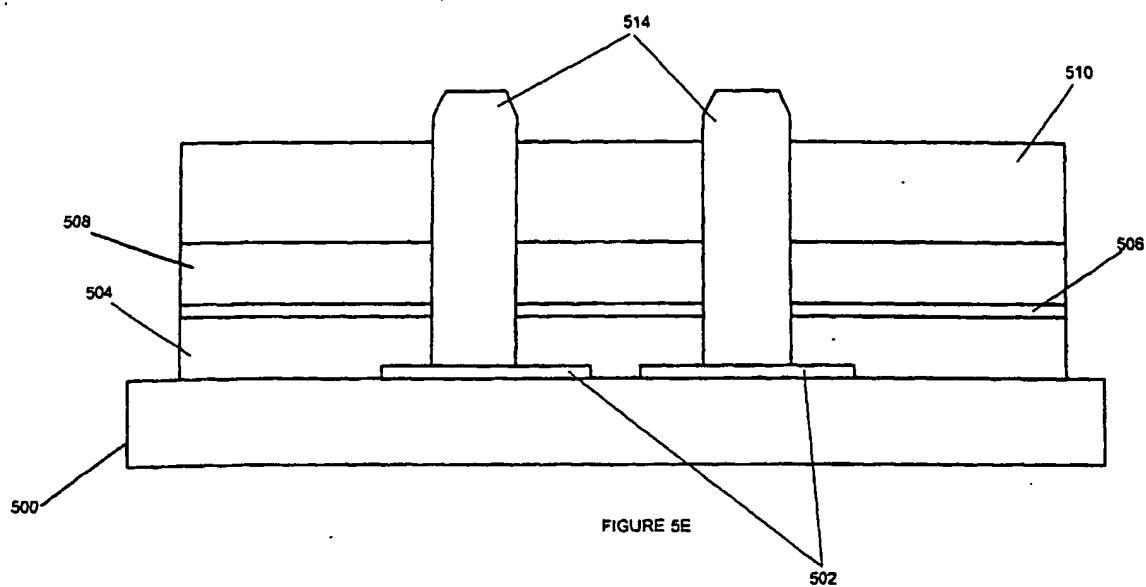
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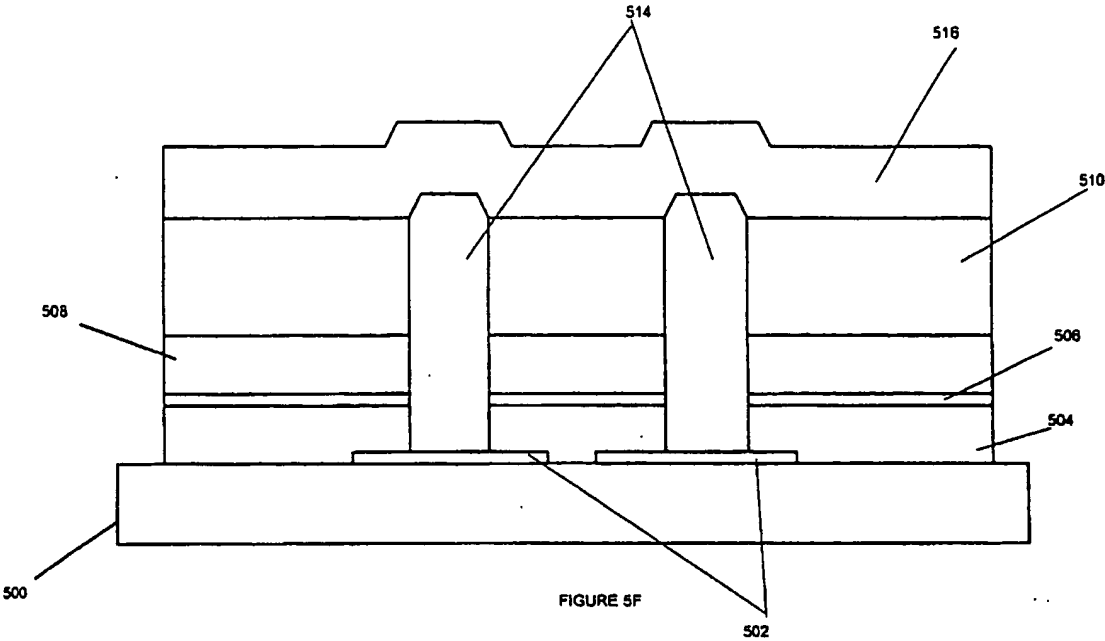


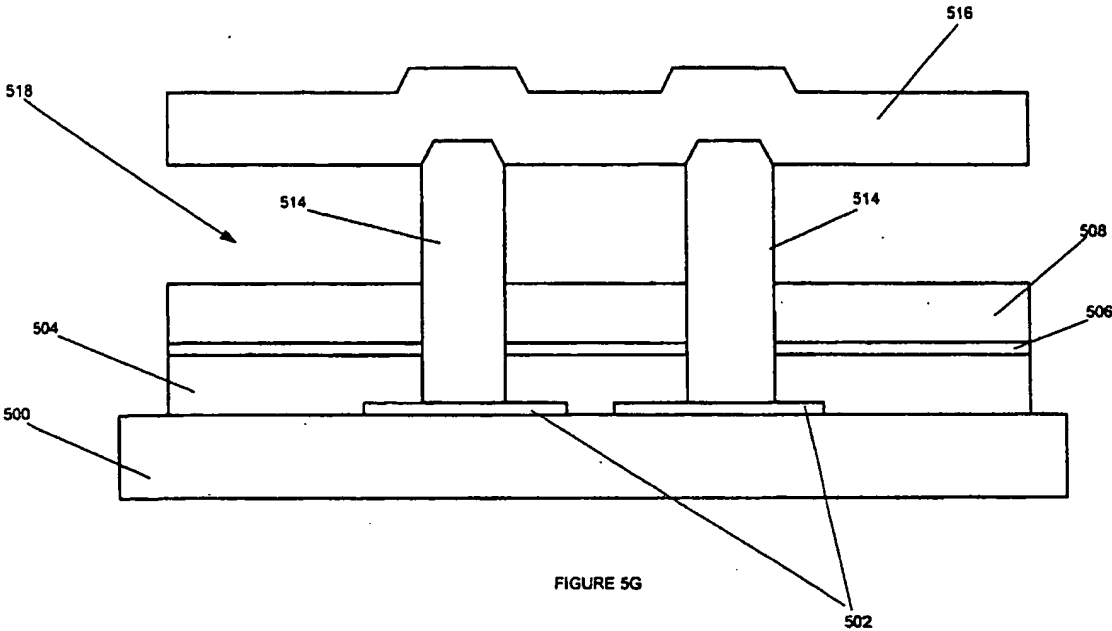
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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/20433

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) : G02F 1/03; G02B 1/10, 26/00, 6/12; G03F 9/00; G03C 5/00

US CL : 359/243, 247, 254, 587, 291; 385/14; 430/5, 322, 323; 216/12

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 359/243, 247, 254, 587, 290-293, 230, 586, 589; 385/14, 18, 24, 50; 430/5, 322, 323, 311; 216/12, 41

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
**NONE**

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- A	US 6,288,824 B1 (KASTALSKY) 11 September 2001 (11.09.2001), column 3, line 46 - column 9, line 15.	9,13,15,17,20,22 ----- 1-8,10-12,14,16, 18,19,21,23,24
A,P	US 6,466,354 B1 (GUDEMAN) 15 October 2002 (15/10/02), column 1, line 12 - column 5, line 38.	1-6,9-11,15,16, 20,21
A	US 6,342,970 B1 (SPERGER et al) 29 January 2002 (29.01.2002), column 1, line 14 - column 8, line 52.	1-6,9-11,15,16, 20,21



Further documents are listed in the continuation of Box C.



See patent family annex.

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## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,474,865 A (VASUDEV) 12 December 1995 (12/12/95), column 3, line 45 - column 9, line 52.	1-5,7-9,12-15,17-20,22-24



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